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BACKGROUND INFORMATION ON DEVELOPMENT OF NATIONAL EMISSION STANDARDS FOR HAZARDOUS AIR POLLUTANTS: ASBESTOS, BERYLLIUM, AND MERCURY

ENVIRONMENTAL PROTECTION AGENCY

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The document provides a detailed discussion of the statements made in the preamble to the National Emission Standards for Hazardous Air Pollutants (asbestos, beryllium, and mercury). The first section of this report covering general provisions, discusses: Applicability of the standards; Approval for construction or modification; Notification of startup; Waiver of compliance; Source reporting; Source sampling and analytical methods. The three remaining sections discuss the following areas for each of the three pollutants, asbestos, beryllium and mercury: (1) health effects; (2) development of the standard; (3) evaluation of comments; (4) environment impact.

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INTRODUCTION

The preamble to the National Emission Standards for Hazardous Air Pollutants (asbestos, beryllium, and mercury) sets forth 1) the bases for the Administrator's determination that asbestos, beryllium, and mercury are hazardous, 2) the derivations of the final standards promulgated, 3) the Environmental Protection Agency's response to the significant comments received, and 4) the principal revisions to the proposed standards. The purpose of this document is to provide a more detailed discussion of the statements made in the preamble.

Section 112 of the Clean Air Act requires the Administrator to establish National Emission Standards for Hazardous Air Pollutants. A hazardous air pollutant is defined as "...an air pollutant to which no ambient air quality standard is applicable and which in the judgment of the Administrator may cause, or contribute to, an increase in mortality or an increase in serious irreversible, or incapacitating reversible, illness." Section 112 defines three steps to be followed in the establishment of emission standards for such pollutants. The required steps and the actions taken pertinent to these requirements follow:

1. Paragraph (b)(1)(A) requires that the Administrator publish a list of those hazardous air pollutants for which he intends to establish emission standards. Publication of the initial list was required within 90 days after the date of enactment of the Clean Air Act, as amended (December 31, 1971). In response to this requirement, an initial list

containing asbestos, beryllium, and mercury was published in the Federal Register on March 31, 1971 (36 F.R. 5931).

2. Paragraph (b)(1)(B) requires that, within 180 days after an air pollutant is included in a published list, the Administrator publish proposed regulations establishing emission standards for such pollutant together with a notice of public hearing within 30 days. Pursuant to this requirement, proposed regulations for the control of emissions of asbestos, beryllium, and mercury were published in the Federal Register on December 7, 1971 (36 F.R. 23939), and Public Hearings were held in New York City, on January 18, 1972 and in Los Angeles on February 15 and 16, 1972. A notice of the Public Hearings was published in the Federal Register on December 16, 1971 (36 F.R. 23931). This hearing notice included a planned hearing on February 1, 1972 in Kansas City, Mo. The hearing scheduled for Kansas City was canceled as a result of a lack of requests to participate.

3. Paragraph (b)(1)(B) further requires that, within 180 days after the publication of a proposed emission standard, the Administrator prescribe an emission standard, unless he has found, on the basis of information presented at Public Hearings, that the pollutant is clearly not a hazardous air pollutant.

The public comment period for the proposed standards closed on March 3, 1972. One hundred and two contributors submitted comments on the proposed standards. The three largest groups represented were industry (54 contributors), State and local air pollution control agencies (20), and groups concerned over the environment (12). A list

of these contributors is included in Table 1. In an attempt to clarify and/or evaluate the comments received, the Agency held numerous discussions with industry groups, State and local air pollution control agencies, other Federal agencies, environmental groups, and experts in fields relevant to the standards and to the comments received.

Table 1

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GENERAL PROVISIONS

The primary purpose of the general provisions is to set forth the administrative requirements related to compliance with the standards. Changes from the proposed regulations were made to improve and clarify the general provisions. The general provisions are summarized and explained below, with changes from the proposed regulations noted.

Applicability of the Standards

The standards are applicable to new, modified, and existing sources. New or modified sources must comply with the standards upon beginning operation. Existing sources must comply within 90 days after final promulgation of the standards, unless granted a waiver of compliance.

Approval for Construction or Modification

Prior to commencement of construction of a new source or modification of an existing one, a source owner is required to obtain the approval of the Administrator. The application must include, among other information, emission estimates in sufficient detail to permit assessment of their validity. The Administrator is required to approve or deny such application within 60 days after submission of sufficient information to evaluate the application.

Notification of Startup

The proposed regulations did not include provisions specifically requiring new or modified sources to notify the Administrator of their startup date before beginning operation. Such a provision, requiring

that the Administrator be notified 30 to 60 days in advance of startup, has been added.

Waiver of Compliance

Under the provisions of Section 112(c)(1)(B)(ii) of the Act, the Administrator may grant existing sources waivers of compliance for up to two years after the effective date of a standard. The conditions for such a waiver are that such time is necessary to install controls, and that steps are taken during this period of the waiver to assure that the health of persons is protected from imminent endangerment.

The general provisions outline in detail procedures for application for waivers, and for approval or denial of such applications. There is no regulatory deadline for applications for a waiver of compliance. However, continued operation in violation of a standard beyond the 90th day after final promulgation is a violation of the Act unless a waiver has been obtained. For this reason, the owner or operator of an existing source should submit the request within 30 days after final promulgation of the standards.

The Administrator has no authority to waive compliance for any period exceeding two years from the effective date of the standard. However, the President may exempt any new, modified, or existing source from compliance with the standards for a period of up to two years, provided technology is not available to implement the standards and the operation of such source is required for reasons of national security. The President may grant exemptions for additional periods of two years or less.

Source Reporting

The proposed regulations required existing sources to submit certain information to the Administrator within 30 days after the effective date of the standards. The promulgated regulations allow 90 days for submission of the information and a form was added to the regulations as Appendix A to help simplify the reporting. The form also includes the information a source must submit when applying for a waiver of compliance and a waiver of initial emission testing.

Requirements for Emission Testing

The proposed regulations required all sources of mercury and beryllium to test their emissions within three months of the effective date and at least once every three months thereafter. Comments received indicated that this provision imposed an unnecessary, and expensive burden on a large number of small sources.

The promulgated regulations require the sources covered by the standards to conduct an initial stack test within 90 days after final promulgation; however, the Administrator may waive the requirement under certain conditions. Periodic emission testing (of sources which have already been certified to be in compliance) is not required by the promulgated standards. The Administrator may require any source to test its emissions at any time under the authority of Section 114 of the Act. Compliance will be monitored by regular inspection of the sources unless such inspection indicates the need for a stack test.

Upon request, the Administrator may waive the initial stack test requirement when a source has requested a waiver of compliance, or has submitted sufficient information to demonstrate that it is in compliance with the applicable standard. Some very small sources may be able to demonstrate that they could not reasonably emit enough of a pollutant to exceed the applicable standard, even if operating completely uncontrolled. Sources which are granted a waiver of emission testing during the period of a waiver of compliance will be required to demonstrate compliance by an initial stack test at the end of the waiver of compliance.

These changes in the emission testing requirements were made primarily in response to comments from small beryllium users. As revised, the requirements are applicable to beryllium and mercury sources.

Source Sampling and Analytical Methods

Three terms are associated with determining compliance by means of source testing: (1) reference method, (2) equivalent method, and (3) alternative method. Reference methods are the preferred methods of sampling and analyzing used to determine compliance. The reference methods for beryllium and mercury are included in appendix B to the regulations. An equivalent method is any method of sampling and analyzing which has been demonstrated to the Administrator's satisfaction to have a consistent and quantitatively known relationship to the reference method under specified conditions. An alternative method is any method of sampling and analyzing which does not meet all the criteria for equivalency but which can be used in specific cases to determine compliance. Alternative methods may be approved

by the Administrator for source testing; however, in cases where determinations of compliance using an alternative method are disputed, use of the reference method or its equivalent will be required by the Administrator.

The reference methods for beryllium and mercury have been used successfully in five tests (beryllium) and seven tests (mercury), respectively. Results from these tests have been reliable, precise, and apparently accurate. Neither method has been submitted to rigorous testing, although EPA has performed limited interlaboratory comparisons and found the methods to have relative standard deviations of 10% to 15%.

A number of comments were received which criticized the complexity of the sampling procedures in the beryllium and mercury reference methods (i.e. the requirements for isokinetic sampling, and the use of wet impingers). Simpler methods could have been adopted, but only with a drastic reduction in accuracy and precision. The characteristics of the gas effluents from the affected mercury and beryllium sources warrant the complex sampling procedures.

The reference method for beryllium is the only beryllium sampling procedure in use that uses both a dry filter and wet impingers. This is required because significant quantities of beryllium have been detected in the wet impingers. During EPA test runs, an average of 39.9% of the total collected beryllium passed through the dry filter and was collected in the wet impingers. From this, EPA has concluded that nonfilterable beryllium is being generated by many sources and

the reference method is substantially more accurate than any other procedure in use.

Recognizing the complexity of the beryllium reference method, an alternative method for beryllium has been approved in the promulgated regulations. The approved alternative method can take many different configurations, each of which would probably yield somewhat different results. The method uses equipment and techniques that are widely accepted, albeit not necessarily as accurate or precise as those specified in the beryllium reference method. The beryllium emissions from a large number of sources covered by the standard are significantly below the 10 gram per day emission limit. Using the alternative method to determine the beryllium emissions from the sources whose emission rate is very low will give results sufficiently below the 10 gram per day emission limit that it will be clear that the sources are complying with the standard. Where the alternative method gives results which indicate that the beryllium emissions from a source are close to the 10 gram per day limit, the Administrator will require that the reference method be used to clearly determine if the source is complying with the standard.

Many comments on the proposed methods were addressed to the possible inaccuracy of mercury analysis below concentrations of 1 $\mu g/m^3$. However, the lowest concentration measured in a stack test to date is 3700 $\mu g/m^3$; the highest is 200,000 $\mu g/m^3$. While mercury analysis may be inaccurate at the relatively low levels encountered in ambient monitoring, its accuracy is adequate for stack testing to monitor

compliance with the hazardous pollutant emission standards. The major threat to accuracy in the concentration ranges generally characteristic of effluent streams is the potential for laboratory contamination; the reference method has been written to emphasize the precautions which must be followed to avoid such contamination.

Mercury sampling trains were operated with three wet impingers and one dry filter either before or after the wet impingers. Separate analysis of the three wet impingers detected mercury in a ratio of 89/10/1, with a following dry filter capturing less than 0.1% of the total mercury collected. This suggests a collection efficiency of 99.9% for the mercury train.

The Administrator has not approved an alternative method for mercury because there is no known method available that is easier to use than the reference method and gives reliable results. The standard for chlor-alkali plants, which are the most difficult to test, allows a source to follow certain housekeeping and maintenance practices to avoid the source testing problems. This is explained in more detail later in this report.

ASBESTOS

The following information augments that given in the preamble to the promulgated regulations.

Health Effects

The proven or suspected effects of asbestos minerals on human health include nonmalignant changes, such as pulmonary and pleural fibrosis, and several types of malignancy, notably of the lung, pleura, and peritoneum. Nearly all the positive evidence of an association between asbestos and human disease has come from studies of occupational groups. With few exceptions, these have consisted of workers engaged in the mining and milling of asbestos, the manufacture of asbestos-containing products (such as textiles and construction materials), and the application and removal of asbestos-containing insulating materials.[53]

Asbestosis, or asbetotic pneumoconiosis, was the first clearly demonstrated adverse effect of asbestos in man.[53] Many persons exposed to asbestos dust develop asbestosis if the dust concentration is high or the duration of exposure is long.[1-7] There is evidence that persons experiencing intense intermittent exposures also are at risk.[52]

A large number of studies have shown that there is an association between occupational exposure to asbestos and a higher-than-expected incidence of bronchogenic cancer.[8-30] Some studies[9] have demonstrated differences in the degree of risk among different occupationally

exposed groups, probably related to dose, as well as to other factors.

Asbestos also has been identified as an etiologic factor in mesothelial malignancies. In 1960, there was a report[47] of 33 cases of pleural mesothelioma in a part of South Africa important for crocidolite mining. For all but two of the patients, the authors discovered likely asbestos contacts two decades or more earlier. However, only 17 of these had had occupational exposure. The remainder had lived near mines or had had household contacts. A large number of studies providing additional information supporting a relationship between asbestos and malignant mesothelioma have been reported since 1960.[30-46,48] Included among them are reports of mesothelioma associated with non-occupational exposures in the neighborhood of asbestos sources.[38,42,47,48] An outstanding feature has been the long period, commonly over 30 years, between the first exposure to asbestos and the appearance of a tumor.[49,50] This disease may occur after a very limited exposure; furthermore, it may occur at exposure levels lower than those required for prevention of radiologically evident asbestosis.[51,52,69]

It has been suggested that the various types of asbestos differ in their relative pathogenicity, but neither laboratory nor epidemiological data are conclusive on this question.[53] All the commercially used forms of asbestos can produce asbestosis. In only relatively few studies has the incidence of malignancies been determined in groups with exposures to a single asbestos type.[53] Where there are data that suggest a lower risk, as in the chrysotile-producing areas of Canada[9,41] and Italy,[54] there are possible explanations for the difference other than

asbestos type. The high incidence of mesothelial tumors in the North Western Cape area of South Africa has led to the suggestion that crocidolite is unusually hazardous, but mesotheliomas have been rare in the Transvaal, where crocidolite is produced also.[55,56] Although one investigator[44] found many mesotheliomas in insulation workers whose exposures had been largely to chrysotile and amosite, others[56,57] have not found the incidence of mesothelioma high in areas where amosite or chrysotile were mined and milled. All epidemiologic studies that appear to indicate differences in pathogenicity among types of asbestos are flawed by their lack of quantitative data on cumulative exposures, fiber characteristics, and the presence of cofactors. The different types, therefore, cannot be graded as to relative risk with respect to either asbestosis or neoplasia.[53]

Direct and indirect evidence that persons other than those working directly with asbestos minerals are being exposed to asbestos is of several types. For example, asbestos fibers can be demonstrated in the lungs of persons not occupationally exposed. In a few geographic areas, pathologic changes regarded as representing a reaction to asbestos, e.g., pleural calcification, have been found in populations with no history of occupational exposure. Asbestos fibers have been shown to be present in ambient air.[53]

Evidence is strong that most human lungs harbor thousands or millions of fibers. Some of these are chrysotile asbestos,[52] and other types of asbestos minerals are probably there also. In most persons not occupationally exposed to asbestos, the numbers of fibers

are relatively small, compared with the numbers found in the occupationally exposed.[52,58] Although there appears no doubt that asbestos fibers are present in many human lungs, there are sources of airborne fibers other than asbestos.[52,59,60] Some are probably derived from the burning of leaves and plant products, such as paper, wood, and coal.[53] Man-made (mostly vitreous) fibers have also been identified in the sediment isolated from human lungs.[53] Talc, often used generously as a dusting powder, may contain a significant amount of tremolite asbestos fibers,[53] as well as chrysotile and anthophyllite. Information is sparse concerning possible increase of fibers in lungs with increasing use of asbestos and concerning the existence of significant differences between urban and rural populations.[53] A comparison of lung tissues obtained in 1934 and 1967 revealed no significant increase in the proportion containing ferruginous bodies[58] (a term used to describe coated fibers found in lung tissues, without regard to whether the fibers are asbestos or other material). This suggested that, despite increasing use of asbestos in New York between 1934 and 1967, fibers of a type producing ferruginous bodies had not been increasing at a corresponding rate. However, there has also been a report of an increase over each decade in asbestos bodies in samples of lungs from persons who died in London in 1936, 1946, and 1956.[58] The significance of the presence of ferruginous bodies (and, in particular, of asbestos fibers and fibrils) in a large percentage of the lungs of adult urban dwellers is as yet unknown.[52] Annual world production of asbestos has risen from 50,000 tons at the turn of this century to 4,000,000 tons[62] at

present.

Studies have implicated asbestos in the development of malignancies in persons not occupationally exposed; i.e., in development of diffuse mesothelioma, a tumor that is uncommon but has been the subject of special attention in recent years.[48,53] Many of the mesotheliomas reported in South Africa[47] were attributed to household and neighborhood exposures in a crocidolite-producing area. Although nonoccupational, these exposures have been described as substantial.[45] Among 76 patients with mesothelioma diagnosed in London Hospital from 1917 to 1964, 31 (40.8%) had occupational exposures to asbestos, 9 (11.8%) had a relative who worked with asbestos, 11 (14.5%) had neither of those backgrounds but had lived within a half-mile of an asbestos source, and 25 (32.9%) had no known contacts.[61] Of 42 persons with mesotheliomas reported in Pennsylvania, 10 had worked in asbestos plants, 8 lived or worked close to an asbestos industry, and 3 were members of families that included asbestos workers; in 11, no history of exposure could be obtained, and the remaining 10 had questionable random exposures.[38] While no quantitative conclusions can be drawn from these studies, which present serious methodologic problems to the epidemiologist, they suggest a risk in household contacts and in residence in the immediate neighborhood of an asbestos plant. There appear to be different levels of risk in different types of occupational exposures, and some of these may be reflected in corresponding household and neighborhood experiences.[53]

In summary: Any of the commercially used asbestos minerals, when inhaled in sufficient numbers, as in uncontrolled occupational

exposures, can cause disabling fibrosis of the lungs. An association between occupational exposures to asbestos and bronchogenic carcinoma has been established, but the dose-response relation and the role of cofactors other than smoking[46] have not been defined. Evidence of a causal association between some but not all exposures to asbestos fibers and diffuse malignant mesotheliomas of the pleura and peritoneum is substantial. Although the different types of asbestos differ in some of their biologic effects, no type can be regarded as free of hazard.[53]

The demonstration of ferruginous bodies, similar to those found in asbestos workers, in a large proportion of randomly selected lung specimens in many parts of the world is presumptive evidence that persons with no occupational contact may have inhaled and retained asbestos. Proof has come in some areas with positive identification of chrysotile asbestos fibers in the lungs.[52] Analyses of community air for asbestos have been too limited to define the sources, concentrations, and distribution of fibers in the environment. The fiber concentrations that have been demonstrated in ambient air are small, compared with those in industry, but data are inadequate for definitive comparisons.[53]

Industrial experience indicates that there is no likelihood of significant asbestosis in nonoccupational exposures.[53] However, any carcinogen (initiator) must be assumed, until otherwise proven, to have discrete, dose-dependent, irreversible and cumulative effects on cells that are transmissible to the cell progeny. Thus, initiation of

malignancy following single small exposures to asbestos is possible, but of a low probability. With frequent or chronic exposure and a low dose rate, the probability of initiation of malignancy is increased. Yet, even under optimal conditions of cell proliferation (in the presence of promoters) these malignant transformations do not lead to instantaneous cancer, but remain latent, often for decades.[51]

The major potential for risk appears to lie in those with direct occupational contacts, indirect occupational contacts, household contacts, or residence in the immediate neighborhood of an asbestos source; and even there, the actual risk is poorly defined. The appearance of a gradient of effect in such groups, however, suggests that there are levels of inhaled asbestos without detectable risk,[53] so that even with respect to neoplasms, consideration must be given to the concept that an inverse relationship exists between dose rate and the latent period; as the dose rate becomes progressively lower, the latent period may approach or exceed the life span of exposed individuals.[51] It is not known what range of respirable airborne asbestos fibers will ultimately be found to have no measurable effects on health. At present, there is no evidence that the small numbers of fibers found in most members of the general population affect health or longevity.[53]

It is probable that the effects of asbestos inhalation are cumulative; that is, low-level and/or intermittent exposure to asbestos over a long time may be equally as important in the etiology of asbestotic disease as high-level and/or continuous exposure over a shorter period. On the other hand, the available evidence does not

indicate that levels of asbestos in most community air cause asbestotic disease. Taking both these considerations into account, and in light of the known serious effects of uncontrolled inhalation of asbestos minerals in occupational situations and the uncertainty as to the shape and character of the dose-response curve for man, the Administrator has made a judgment that, in order to provide an ample margin of safety to protect the public health from asbestos, it is necessary to control emissions from major man-made sources of asbestos emissions into the atmosphere, but that it is not necessary to prohibit all emissions. In making this judgment, the Administrator relied largely on the National Academy of Sciences' report on asbestos[53] which reached similar conclusions.

Development of the Standard

An important consideration in the development of the asbestos standard was the former lack of satisfactory methods of sampling, identifying, and measuring airborne asbestos, which could be used to establish dose-response relationships. Only within recent years have methods for determining concentrations of fibers for industrial hygiene purposes been standardized;[51,63,66,68] they use samples collected on membrane filters in which fibers are counted with phase contrast illumination. Electron microscopic methods give a much more complete indication of the total fiber content of the air; but when the need for fiber identification is included, they are tedious and relatively expensive for routine use.[51]

The aforementioned phase contrast illumination method for quantifying occupational exposures to asbestos determines the number of fibers (longer than 5 microns) per unit volume of air sampled; no chemical analyses are performed to verify that the fibers are asbestos, and studies have shown that the method accounts for less than 5% of the total number of fibers present in a sample. Nor is there any evidence that only those fibers longer than 5 microns are significant in the production of adverse health effects in humans.

It is impossible to specify with reasonable accuracy an ambient concentration for asbestos which provides an ample margin of safety to protect the public health. The needed definition of a dose-response relationship is not available. Research and analysis in this area have been hampered severely by two factors: (1) The effects of inhaling asbestos do not usually become evident until long after the exposure, i.e., a 30-year latent period is not uncommon; consequently, exposure histories can only be roughly estimated; and (2) until recently, there were no reliable techniques for measuring ambient concentrations of asbestos; therefore, the concentrations to which the public might be exposed remained unknown. In addition, a satisfactory means of measuring asbestos emissions is still unavailable.

W. E. Davis & Associates were contracted to study the sources of asbestos emissions. Their emissions inventory was based on information obtained from production and reprocessing companies, 1968 production and use statistics from the Bureau of Mines and emission factors developed by Davis personnel. Although these emission factors

are not based on quantitative data (i.e. emission tests), they are considered adequate for the purpose of identifying major sources. The estimated emissions of asbestos from sources studied by Davis Associates are as follows.[70]

ASBESTOS EMISSIONS

1 9 6 8

SOURCE CATEGORY	SOURCE GROUP	SHORT TONS
MINING AND OTHER BASIC PROCESSING	Mining and Milling	5,610
REPROCESSING		
	Friction Materials	312
	Asbestos Cement Products	205
	Textiles	18
	Paper	15
	Floor Tile	100
	Miscellaneous	28
CONSUMPTIVE USES		
	Construction	61
	Brake Linings	190
	Steel Fireproofing	15
	Insulating Cement	25
INCINERATION OR OTHER DISPOSAL		NA
NA-Data not available.	TOTAL	6,579

Considering this and other information, the major sources identified were: asbestos mine-mill complexes; asbestos users, both manufacture of asbestos-containing products and fabrication operations using asbestos products; demolition; and spray application of asbestos products to buildings and equipment. Although demolition was not identified as a major source in the Davis report which was published in 1970, it was so identified in the National Academy of Sciences' report[53] which was

published in 1971.

The preamble to the promulgated regulations describes the sources covered by the promulgated standard, the changes made to the standard between proposal and promulgation, and the factors the Administrator considered in making his final judgments.

The proposed standard for asbestos was not given in terms of numerical values. Instead, the standard was expressed in terms of required control practices that would have limited asbestos emissions to an acceptable level. In part, control of atmospheric emissions would have been achieved by:

1. Utilizing industrial fabric filters to clean forced exhaust gases from asbestos mining, milling, and manufacturing industries and from fabricating operations that involve materials containing asbestos.

2. Eliminating visible emissions of particulate matter from ore dumps, open storage areas, external conveyors, and tailing dumps associated with asbestos mining and milling facilities as well as from manufacturing and fabricating operations carried out with asbestos-containing materials in areas directly open to the atmosphere.

3. Prohibiting certain applications of asbestos fireproofing and insulation by spraying processes.

Also, indirect atmospheric emissions of particulate matter would have been controlled at manufacturing and fabricating sites where visible emissions normally result from operations using asbestos materials. The maximum allowable emissions would have been equivalent to those attained by either ventilating an entire work space through a fabric filter or by hooding emission sources and subsequently passing the required dust-control air through a fabric filter.

The promulgated standard is not given in terms of numerical values. The provisions of the promulgated standard are limitations on visible emissions, or, as an option in some cases, the use of designated equipment, requirements that certain procedures be followed, and prohibitions on the use of certain materials or of certain operations. These provisions are included because of the impossibility at this time of prescribing and enforcing allowable numerical concentrations or mass emission limitations known to provide an ample margin of safety. The alternative of no control of the sources subject to this standard was rejected because of the significant health hazard of unregulated emissions of asbestos into the atmosphere from the designated major sources.

Evaluation of Comments

Many representatives of industry, State and local governments, the academic community, and environmental groups expressed their views on the proposed standard for asbestos. All of the comments received during the comment period were evaluated, and the proposed standard was revised to reflect this evaluation. More comments were received on the proposed asbestos standard than either the proposed beryllium or mercury standards. A discussion of the evaluation of the comments and the resulting action by EPA follows:

1. Comments received questioned the listing of asbestos as a hazardous pollutant. While admitting the hazardous nature of occupational exposures to asbestos, they suggested that ambient concentrations of asbestos are not hazardous. The Administrator's reasons for considering asbestos a hazardous air pollutant are given in the section of this report which discusses the health effects of asbestos.

2. Some of the comments received after proposal of the standard suggested that the wearing of brake linings is a major source of asbestos emissions. As the Davis report indicates, wear from asbestos brake linings does generate a substantial amount of asbestos emissions, primarily in urban areas. This was not considered a major source of asbestos emissions because there is evidence[71,72,73] which shows that only a very small proportion of the asbestos worn from brake linings is released as free fiber; the remainder is converted into some other nonfibrous mineral, i.e., the material is no longer asbestos, as a result of the extreme temperatures generated on the lining surface.

3. Comments received indicated that the asbestos standard should be a numerical emission standard. Some of the difficulties of this approach are outlined in the section of this report on development of the standard.

It has been determined not to be practicable, at this time, to establish allowable numerical concentrations or mass emission limits for asbestos. Satisfactory means of measuring ambient asbestos concentrations have only recently been developed, and satisfactory means of measuring asbestos emissions are still unavailable. Even if satisfactory means of measuring asbestos emissions did exist, the previous unavailability of a satisfactory means of measuring ambient levels of asbestos makes it impossible to estimate even roughly the quantitative relationship between asbestos-caused illness and the doses which caused those illnesses. This is a major problem, since some asbestos caused illnesses have a 30-year latency period.

EPA considered the possibility of banning production, processing, and use of asbestos or banning all emissions of asbestos to the atmosphere but rejected these approaches for the following reasons: (1) The available evidence relating to the health hazards of asbestos does not suggest that such prohibitions are necessary to protect public health; rather the evidence now available suggests that there are levels of asbestos exposure that will not be associated with any detectable risk, although these levels are not known.[53] (2) The difficulty of measuring "zero" emissions of any pollutant, together with the presence of asbestos in many commonly used materials, make such prohibitions impracticable. Either approach would result in the prohibition of many activities which are extremely important. Such prohibitions would mean, for example, that demolition of any building containing asbestos fireproofing or insulating materials would have to be prohibited as would the use of materials containing even trace amounts of asbestos which could escape into the atmosphere.

4. Many comments questioned the need for regulating mine-mill complex emissions other than those from process gas streams. Evaluation of these comments led to revisions in the standard.

As applied to mines, the proposed standard would have limited the emissions from drilling operations and prohibited visible emissions of particulate matter from mine roads surfaced with asbestos tailings. The Bureau of Mines has prescribed health and safety regulations (30 CFR 55.5) for the purpose of protecting life, the promotion of health and safety, and the prevention of accidents in open pit metal

and nonmetallic mines. As related to asbestos mines, these regulations prohibit persons working in a mine from being exposed to asbestos concentrations which exceed the threshold limit value adopted by the American Conference of Governmental Industrial Hygienists.[64] The regulations specify that respiratory shall not be used to prevent persons from being exposed to asbestos where environmental measures are available. For drilling operations, the regulations require that the holes be collared and drilled wet. The regulations recommend that haulage roads, rock transfer points, crushers and other points where dust (asbestos) is produced sufficient to cause a health or safety hazard be wetted down as often as necessary unless the dust is controlled adequately by other means. In the judgment of the Administrator, implementation of these regulations will prevent asbestos mines from being a major source which must be covered by the promulgated standard. Furthermore, the public is sufficiently removed from the mine work environment that their exposure should be significantly less than that of the workers in the work environment. Accordingly, the promulgated standard does not apply to drilling operations or roadways at mine locations.

For asbestos mills, the proposed standard would have applied to ore dumps, open storage areas for asbestos materials, tailings dumps, ore dryers, air for processing ore, air for exhausting particulate material from work areas, and any milling operation which continuously generates in-plant visible emissions. The promulgated standard prohibits visible emissions from any part of the mill, but it does not apply to

dumps of asbestos tailings or open storage of asbestos ores. The Bureau of Mines' regulations previously referenced and regulations issued by the Occupational Safety and Health Administration (20 CFR 1910.93a) protect workers from the hazards of air contaminants in the work environment. The Occupational Safety and Health Administration regulations were promulgated on June 7, 1972. The regulations are intended to protect the health of employees from asbestos exposure by means of engineering controls (i.e. isolation, enclosures, and dust collection) rather than by personal protective equipment. It is the judgment of the Administrator that measures taken to comply with the Bureau of Mines and Occupational Safety and Health Administration regulations to protect the health of persons who work in proximity to dumps and open storage areas will prevent the dumps and storage areas from being major sources of asbestos emissions.

5. Other comments were directed at the proposed provisions for manufacturing and fabricating uses of asbestos. The proposed standard would have applied to buildings, structures or facilities within which any fabricating or manufacturing operation is carried on which involves the use of asbestos materials. Comments received on the proposed standard indicated that the requirements for fabricating and manufacturing operations were confusing. Much of the confusion was created by the use of terms such as "any," "continuously," and "forced gas streams." The promulgated standard is more definitive as to applicability of the provisions. The promulgated standard prohibits visible emissions from the nine manufacturing operations

which, in the judgment of the Administrator, are major sources of asbestos. The promulgated standard does not cover fabrication operations. Of all fabrication operations, only those operations at new construction sites are considered to be major sources of asbestos emissions. The Occupational Safety and Health Administration regulations specify that all hand- or power-operated tools (i.e. saws, scorers, abrasive wheels, and drills) which produce asbestos dust be provided with dust collection systems. In the judgment of the Administrator, implementation of these regulations will prevent fabrication operations from being a major source which must be covered by the promulgated standard.

The nine manufacturing sources which are covered by the promulgated standard are listed below:

Manufacture of Asbestos Textiles

Manufacture of Asbestos Cement Products

Manufacture of Asbestos Fireproofing and Insulation

Manufacture of Asbestos Friction Products

Manufacture of Asbestos Paper

Manufacture of Asbestos Floor Tile

Manufacture of Paints, Coatings, Caulks, Adhesives, and Sealants

Manufacture of Plastics and Rubber Materials

Manufacture of Chlorine

6. Some comments suggested that a complete ban on open spraying of asbestos-containing materials unnecessarily restricted a wide variety of products, some of which contain trace amounts of asbestos.

Evaluation of the comments led to revisions of the standard.

The proposed standard would have prohibited the spraying of any material containing asbestos on any portion of a building or structure, prohibited the spraying of any material containing asbestos in an area directly open to the atmosphere, and limited emissions from all other spraying of any material containing asbestos to the amount which would be emitted if specified air-cleaning equipment were used. The proposed standard would have: (1) prohibited the use of materials containing only the trace amounts of asbestos which occur in numerous natural substances, (2) prohibited the use of materials to which very small quantities of asbestos are added in order to enhance their effectiveness, and (3) prohibited the use of materials in which the asbestos is strongly bound and which would not generate particulate asbestos emissions. The promulgated standard applies to those uses of spray-on asbestos materials which could generate major emissions of particulate asbestos material. For those spray-on materials used to insulate or fireproof buildings, structures, pipes and conduits, the standard limits the asbestos content to no more than one percent. Materials currently used contain from 10 to 80 percent asbestos. The intent of the one percent limit is to ban the use of materials which contain significant quantities of asbestos, but to allow the use of materials which would (1) contain trace amounts of asbestos which occur in numerous natural substances, and (2) include very small quantities of asbestos (less than one percent) added to enhance the material's effectiveness. Although a standardized reference method

has not been developed to quantitatively determine the content of asbestos in a material, there are acceptable methods available, based on electron microscopy, which independent laboratories have developed. Determining the asbestos content of a material with these methods costs approximately $300, and the results are accurate within plus or minus fifty percent; these limits on accuracy were taken into account in establishing the one-percent limitation.

7. One comment questioned the practicability and enforceability of a no visible emissions provision for demolition; such a provision would, in effect, prohibit repair or demolition in many instances. Evaluation of the comment confirmed its validity, and the standard was revised.

The promulgated standard specifies certain work practices which must be followed when demolishing certain buildings or structures. The standard covers institutional, industrial, and commercial buildings or structures, including apartment houses having more than four dwelling units, which contain friable asbestos material. This coverage is based on the National Academy of Sciences' report[53] which states "In general, single-family residential structures contain only small amounts of asbestos insulation. Demolition of industrial and commercial buildings that have been fireproofed with asbestos-containing materials will prove to be an emission source in the future, requiring control measures." Apartment houses with four dwelling units or less are considered to be equivalent to single-family residential structures. The standard requires that the Administrator be notified at least 20

days prior to the commencement of demolition.

8. Other comments indicated that disposal of asbestos wastes should be covered by the standard. These comments were evaluated and rejected.

Consideration was given to including provisions in the standard requiring proper disposal of the asbestos material generated during demolition and collected in control devices used to comply with the requirements of this standard. It was decided that this was not necessary because the Occupational Safety and Health Administration regulations [29 CFR 1910.93a (h)] include housekeeping and waste disposal requirements. These regulations require that any asbestos waste, consigned for disposal, be collected and disposed of in sealed impermeable bags or other closed, impermeable containers.

Environmental Impact

The asbestos standard will substantially reduce asbestos emissions. A five-year projection of estimated control costs and emission reductions was prepared for EPA in 1972.[74] The estimated emissions for 1970 and projected reductions for 1977 are as follows:

Source Category	Number of Plants (1970)	Emissions (tons/year) 1970 Current Control	1977 Current Control	1977 Meeting Standard
Milling Products	9	3,860	5,440	218
Asbestos Cement	48	206	290	58
Floor Tile	18	101	142	28
Friction Material	30	314	441	88
Asbestos Paper	29	15	21	2
Asbestos Textiles	34	20	28	15

The number of affected sources and the amount of emission reduction for demolition, spray application, and other manufacturing sources has not been estimated.

Two potentially adverse environmental effects of the asbestos standard have been identified as:

1. The asbestos materials which will be collected in control devices and generated during demolition will have to be disposed of or recycled.

2. Materials, such as mineral wool, fiberglass, and ceramic wool, will be substituted for asbestos presently contained in spray-applied fireproofing and insulating materials.

Dry asbestos-containing particulate matter captured by fabric filters is expected to account for the major portion of the increase in asbestos-containing wastes; the increased usage of wet collectors which would generate larger quantities of asbestos-containing sludge is anticipated to be minimal. A preliminary evaluation indicates that in some manufacturing operations a major portion of the asbestos materials collected by fabric filters are either recycled to the process or can be marketed for other uses. For example, one asbestos textile mill recycles large quantities of longer-fiber asbestos for process use and sells more than 90 percent of the remaining collected materials to a brake lining manufacturer. Consequently, a significant portion of the increased quantities of "waste" asbestos-containing materials which will result from the implementation of the standard will not require disposal. Proper solid and liquid waste management practices

are available which can ensure the environmentally acceptable ultimate disposal of asbestos wastes. Occupational Safety and Health Administration regulations [29 CFR 1910.93a(h)] require that manufacturing wastes which contain dry, unbound asbestos be disposed of in sealed, impermeable bags or other closed, impermeable containers to control potential airborne asbestos emissions. The possible contamination of ground water supplies with asbestos from the landfill disposal of asbestos sludges and dry wastes has not been identified as a potential problem; the asbestos materials will be disposed of in impermeable containers and even if they were not, there is no evidence which indicates that such materials would be carried to surface or underground water supplies.

The substitution of mineral wool, ceramic wool, and fiberglass for asbestos is not known to be a problem. There is no evidence that these materials cause health effects in the concentrations found in occupational or ambient environments.

Economic Impact

Although the standard was not based on economic considerations, EPA is aware of the impact[74] and considers it to be reasonable. Costs among the various sources covered by the standard are variable. Although the standard may adversely effect some individual plants or companies which are marginal operations, it appears that such effects will be minimal and the impact to the asbestos industries as a whole will not be large.

Approximately 15 percent of the asbestos consumed in the United States is obtained from domestic production and 85 percent

from imports. Canada, with Quebec having the world's largest deposit, provides about 90 percent of the asbestos imports and the Republic of South Africa most of the rest. U. S. production has tripled since 1956, representing a growth rate of about 7 percent per year. Domestic consumption is growing at 3 percent per year.

The basic processing of domestic asbestos ores is carried out by nine companies owning nine mine-mill operations with production capacities ranging from 200 to 65,000 tons per year.

Although mining is not covered under the standard, the associated milling operations are subject to controls. Milling facilities are located at or within 60 miles of the mine site with the exception that the small-volume North Carolina output is transferred to a mill in Baltimore, Maryland. The estimated total investment cost of $400,000 required of the nine existing mills for compliance with the standard yields an annualized cost range of $0.50 to approximately $6.00 per ton, with the average being approximately $1.00 per ton and the maximum figure applying to facilities accounting for less than 5 percent of domestic production. These costs represent a range of less than 1 to 7 percent of the average selling price per short ton of domestic asbestos in 1969 of $86.22, F.O.B. mine. Investment outlays range from $3,000 for a partially controlled mill of 200 ton/year capacity to $225,000 for a partially controlled mill of 65,000 ton/year capacity.

Because asbestos prices are determined in the world market and U. S. production supplies only a small fraction of the U. S. consumption, it is expected that domestic plants will in general not be able to pass on their higher costs in the form of price increases. However, no plants are

expected to shut down due solely to the cost burdens imposed by the standard.

For the major categories of industries that manufacture products containing asbestos, i.e., producers of asbestos-cement products, asbestos-containing floor tile, asbestos-reinforced friction materials, asbestos paper, and asbestos textiles, a total additional investment of about $5,000,000 is estimated to be required to bring existing, partially controlled sources into compliance with the standard. An annualized cost of 0.4 percent of the output product value will be required. In terms of alterations in product price, there would result an average increase of 0.4 percent; the most significant increase would be 5.2 percent for asbestos textile products.

For the categories of manufacturers that process small quantities of commercial asbestos, e.g., producers of paints and coatings, a total additional investment of approximately $1,500,000 will be required to bring existing sources into compliance with the standard. This represents an annualized cost of less than 1 percent of product value.

The use of asbestos in spray-applied fireproofing and insulation represents less than 0.5 percent of the annual domestic consumption of asbestos. No major impact on the price of asbestos or upon producers of asbestos would result from the limitations on asbestos content of spray-applied asbestos fireproofing and insulation. Further, increased costs for substitute materials, available or scheduled for introduction in the near future, range from zero to a maximum of 15 percent. The use of these materials, some of which are asbestos-free, does not require new equipment or extensive retraining of personnel.

It is estimated that the wetting and removal of asbestos fireproofing and pipe insulating materials prior to the demolition of buildings or structures will increase demolition costs by less than 8 percent. Based on a rough estimate that 4,000 apartment buildings and 22,000 commercial or industrial buildings are demolished annually at a total cost of approximately $550 million, compliance with the standard would cost about $45 million. Further, since demolition costs represent a minor portion (probably less than 10 percent) of the overall costs of rehabilitation and construction projects, the increase in demolition costs as a result of the promulgated asbestos standard is insignificant.

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BERYLLIUM

The following information augments that given in the preamble to the promulgated regulations.

Health Effects

Beryllium and many of its compounds are considered to be among the most toxic and hazardous of the nonradioactive substances in industrial use. The proven effects of airborne beryllium materials on human health include both acute and chronic inhalation effects as well as skin and conjunctival effects,[1,2,3] and there is limited evidence that an association exists between the immune status of the host and its vulnerability to beryllium inhalation.[1,3,11]

The first such disease to be recognized was an acute inflammatory reaction in the respiratory tract of man. Only water-soluble compounds of beryllium are thought to cause this inflammatory response in the respiratory tract;[1] however, many relatively insoluble beryllium compounds and the pure metal, in addition to the soluble compounds, are suspected as potential causes of acute pneumonitis.[3]

The course of acute beryllium-induced pneumonitis depends upon exposure levels.[1] Overwhelming acute pneumonitis, progressing to pulmonary edema and death,[6] may result from inhalation of heavily contaminated air. Exposures to lower concentrations of beryllium (100-400 $\mu g/m^3$) may cause an illness with insidious onset, characterized by non-productive cough, substernal pain, fatigue, weight loss,[2,3,8] and the subsequent appearance, one to three weeks after initial symptoms, of a hazy chest radiographic pattern.[3]

Provided that the beryllium exposure is terminated, complete recovery usually occurs in one to four weeks.[2,3] The acute form of beryllium disease has been observed, with a single reported exception,[7] only in persons with occupational beryllium exposures.

The chronic form of beryllium disease, with a sometimes long latent period[3] that renders difficult the retrospective calculation of the nature and magnitude of the exposure, is a progressive granulomatous disease, located in the interstitial tissues and the alveolar walls of the lung,[1,2,3] that develops not only in a significant percentage of acute cases,[3] but has been observed in individuals who never have been employed in a beryllium industry.[3] Symptoms of chronic beryllium disease are similar to those of the acute disease and include shortness of breath, non-productive cough, chest pain, fatigue, and weight loss.[3,13] However, unlike the acute disease, the chronic form may have a prolonged progressive course, and systemic manifestations, such as enlargement of right heart or of liver or spleen, cyanosis, digital "clubbing", and kidney stones, have been reported.[10,12] Beryllium-induced cancers have been demonstrated in laboratory animals[1,2,3] (monkeys, rabbits, guinea pigs, hamsters, and rats). Insufficient data are available to incriminate beryllium as a human carcinogen,[1,2,3,6] but there is no mechanism for the total elimination of beryllium body burdens, and the resulting possibly long residence time[3] may indeed enhance the opportunity for cancer induction.

The Beryllium Registry[5] now contains over 800 cases, but since many of these cases are most likely due to exposure prior to the institution of controls, proper assessment of the period of exposure is not always possible.[1,2] It is known, however, that chronic beryllium disease is not only associated with activities involving extraction processes, but that 64 Registry cases resulted from exposure during machining operations (37 from machining the pure metal, 27 from machining copper alloys whose maximum beryllium content was 4%); the chronic disease has also been associated with foundry operations where 4% beryllium-copper (BeCu) alloy was melted and diluted to 2% BeCu alloy. There are at least 45 cases of non-occupationally-incurred disease on file with the Beryllium Registry.

Retrospective studies of the concentrations of beryllium that resulted in some cases of chronic beryllium disease from non-occupational exposure have concluded that the lowest concentration which produced disease was greater than 0.01 $\mu g/m^3$, and probably less than 0.10 $\mu g/m^3$.[4]

In 1949, when it became apparent that beryllium was a toxic material, the Atomic Energy Commission (AEC) adopted a limit for beryllium concentrations in community air (i.e., 0.01 µg of beryllium per cubic meter of air averaged over a 30-day period). Beryllium refining companies holding contracts with the AEC to operate AEC-owned refinery facilities and expand their own refinery capacity to meet AEC's beryllium requirements, were required to

observe the community air limit. With the termination of these contracts in the 1961-1963 period due to a reduction in AEC requirements for beryllium, the refineries were no longer subject to the AEC community air limit. The AEC's health and safety requirements, however, have continued to apply to all AEC-owned facilities, some of which fabricate and assemble beryllium parts. In the period since the implementation of the AEC guideline, no reported cases of chronic beryllium disease have occurred as a result of community exposure,[1,6] and the Committee on Toxicology of the National Academy of Sciences concluded[1] that the average concentration of 0.01 $\mu g/m^3$ for a 30-day average is a proven safe level of exposure.

Emissions of beryllium from the sources covered by the proposed EPA standard occur as dust, fume, or mist. Alteration of a beryllium product by burning, grinding, cutting, or other physical means can, if uncontrolled, produce a significant hazard. In contrast, beryllium alloys in the form of strip or other wrought products are sometimes utilized in operations that do not generate significant dust, fume, or mist. The number of operations that use beryllium is estimated to be in the thousands.[2] Approximately 300 operations, such as machine shops, ceramic plants, propellant plants, extraction plants, and foundries, comprise the major users of beryllium that could cause emissions to the atmosphere. Annual U.S. consumption of beryllium has grown from an estimated 1438 tons in 1948[10] to 9511 tons in 1970.[14]

Data from the National Air Surveillance Networks do not show the existence of dangerous levels in the ambient atmosphere. Nevertheless,

because of the known serious and sometimes lethal effects of uncontrolled inhalation of beryllium dust, fume, or mist, and uncertainty as to the shape and character of the dose-response curve in man, it would be highly imprudent to permit additional contamination of the public environment with these forms of beryllium. Continued use at minimal risk to the public requires that the sources of beryllium dust, fume, or mist emissions into the atmosphere be defined and controlled. In the absence of such controls, local concentrations might at times approach those in occupational sites.

Since 1966, emissions from the firing of rockets utilizing beryllium as a propellant component have been limited by U.S. Public Health Service policy; since 1967, they have been limited as well by U.S. Department of Defense directive. Both agencies direct that emissions from this source shall not cause atmospheric concentrations of soluble beryllium compounds to exceed 75 μg-minutes/m^3 of air within 10 to 60 minutes, accumulated during any 2 consecutive weeks, in any area accessible to the general public or at any place of human habitation.

The sources covered by the promulgated standard, if not controlled, can potentially release amounts of beryllium that will produce concentrations greater than 0.01 $\mu g/m^3$ in the ambient air. All sources known to have caused, or to have the potential to cause, dangerous levels are covered by the beryllium standard.

Development of the Standard

The basic approach used to develop a standard for beryllium was to identify an ambient level sufficient to protect public health from the effects of beryllium and then relate emissions to this ambient level by using meteorological procedures. In order to determine what sources of beryllium emissions were capable of exceeding the ambient guideline (0.01 $\mu g/m^3$ - 30-day average), EPA conducted a characterization study of the sources of beryllium. The study included contracts[15,16] to develop information on beryllium emission sources and communications with industrial representatives, trade associations, and air pollution control experts. Further, visits were made to representative plants which had been identified as sources of beryllium emissions. Some of these plants were tested for beryllium emissions, and the results of the tests are presented in Table 2.

One difficulty in developing a national emission standard for beryllium was the application of one national meteorological model to the large number of beryllium sources that are characterized by differing emission parameters, climatic conditions, and topography. The release of beryllium into the atmosphere varies from continuous to intermittent, from release at essentially ground level to several hundred feet through tall stacks, and from a single stack to a group of stacks at a single source spread over a large area.

A maximum allowable emission rate of 10 grams/24-hour period was calculated by assuming meteorological conditions which are conducive to

Table 2.

EPA Beryllium Emission Testing Results

Date	Type Plant	Emissions (grams/24-hour period)
Feb. 1972	Large ceramic plant[17]	0.16
Aug. 1971	*Large pure Be machine shop[18]	0.16
Aug., Dec. 1971	*Large pure Be machine shop[19]	4.2**
Aug. 1971	*Beryllium foundry[20]	.08† 3.08††

*Emissions based on 8-hour per day operation since the plants operate only one shift and are shut down 16 hours.
**In a previous test an emission rate of 11.7 grams/day was measured. A baghouse filter bag had ruptured and was indicated to be the source of the high emission.
†After baghouse.
††Before baghouse.

poor dispersion and the ambient guideline concentration (0.01 $\mu g/m^3$ - 30-day average). These assumptions were employed in order to provide an ample margin of safety to protect public health, i.e., to be reasonably confident that the calculated maximum emission rate would not result in a 30-day average ambient concentration in excess of 0.01 $\mu g/m^3$ under any realistically possible circumstances. The assumptions and equations used to make the dispersion estimate are given in the background information report[21] which was published at the time the standards were proposed.

The four existing beryllium extraction plants have structured their facilities in configurations which are designed to meet a 0.01 $\mu g/m^3$ (30-day average) level, primarily by dispersing emissions through the use of multiple emission points. No non-occupational cases of chronic beryllium disease have been identified in the vicinity of these sources since 1949. The community health record of the extraction plants for a period of more than 20 years was determined to be sufficient evidence that this compliance method is workable and provides an ample margin of safety to protect public health. Consequently, as an alternative to complying with the 10 grams/24-hour period maximum emission, the proposed standard also allowed the operator of any affected source to demonstrate compliance by not exceeding the ambient beryllium guideline (0.01 $\mu g/m^3$ - 30-day average). In order to demonstrate compliance with the ambient option, the operator of a source was required to operate an EPA-approved monitoring network designed to measure the maximum ambient beryllium concentration.

Because of the inherent high concentrations possible during rocket motor propellant firing and the non-sustained (intermittent) nature of this source of beryllium emissions, a different standard was developed for this source category. A dose of a high concentration of beryllium for a relatively short period may pose a beryllium hazard to public health and must be prevented even though the 30-day ambient average of 0.01 $\mu g/m^3$ may not be exceeded. The Committee on Toxicology of the National Academy of Sciences recommended,[1] after studying the intermittent exposure problem in 1966, two time weighted beryllium exposure levels, 75 μg-minutes/m^3 for soluble beryllium compounds and low-fired beryllium oxide and 1500 μg-minutes/m^3 for high-fired beryllium oxide (within the limits of 10 to 60 minutes, accumulated during any consecutive two-week period). EPA has applied the more restrictive of these two recommended levels to rocket motor test facilities and propellant disposal sites. This level was applied since the composition of the combustion products of the intermittent sources covered may contain soluble beryllium compounds or low-fired beryllium oxides depending on the type of propellant tested or waste disposed of and the firing conditions. Thus, intermittent beryllium sources were required to design test firings and the disposal of beryllium propellant to not exceed a time weighted concentration of 75 μg-minutes/m^3 (within the limits of 10 to 60 minutes accumulated during any consecutive two-week period).

Beryllium sources are generally well controlled; however, under

certain conditions, processes and control equipment can be operated so that beryllium emissions will result in excessive ambient concentrations. The following sources were determined to be capable of generating emissions which could exceed the ambient beryllium guideline and, therefore, were covered by the proposed standard:

Beryllium extraction plants

Beryllium metal and alloy machine shops

Beryllium foundries

Beryllium ceramic plants

Incinerators that dispose of beryllium-containing wastes

Power plants which burn coal that typically contains from 1 to 2 parts per million of beryllium are known to be sources of beryllium emissions, but were not covered by the proposed beryllium standard. Beryllium emissions from power plants may be larger than emissions from some sources that were covered by the proposed standard; however, due to the dispersion provided by tall stacks and hot gases characteristic of these sources, the attainment of ambient concentrations in excess of 0.01 $\mu g/m^3$ (30-day average) has been determined to be unlikely even in restrictive dispersion situations.

The proposed beryllium standard was reviewed by several governmental and expert advisory groups prior to being proposed in the Federal Register on December 7, 1971. Simultaneously, EPA published a background information report[21] which gives a summary of information available prior to proposal and the developmental approach used to establish the standard.

Evaluation of Comments

All of the comments received during the comment period were evaluated and the proposed standard was revised to reflect this evaluation. The revised standard was reviewed by several advisory groups prior to final promulgation. A discussion of evaluation of the comments and the resulting action by EPA follows:

1. Comments on the proposed standard for beryllium were received which claimed that the ambient compliance option was inconsistent with Section 112 of the Act because it is not an emission standard and that enforcement would be difficult. This comment was given much consideration and it was concluded that under certain conditions, compliance with an ambient level can be considered an emission standard because emissions must be limited to the extent necessary to avoid exceeding the established ambient level. In the case of beryllium, the effectiveness of this mode of compliance has been proven over the past 20 years in the beryllium extraction industry. The community health record of the extraction plant since 1949 is considered sufficient evidence that the use of an ambient level is workable and provides an ample margin of safety.

The principle of allowing compliance with the beryllium standard by ambient monitoring has been retained in the promulgated standard; however, the applicability of this option has been restricted for enforcement purposes. The proposed standard would have allowed all sources of beryllium to choose between meeting the 10-gram-per-24-hour emission limit and complying by use of ambient monitoring to insure that the 0.01 $\mu g/m^3$ (30-day average)

is not exceeded. Enforcement of this provision would have been very difficult due to the problem of distinguishing between and among sources of beryllium emissions. The standard was revised to allow this option only to existing sources which have at least three years of current ambient air quality data which demonstrates to EPA's satisfaction that the 0.01 $\mu g/m^3$ (30-day average) can be met in the vicinity of the source. A minimum of three years of data was judged to be necessary to demonstrate that the ambient guideline of 0.01 $\mu g/m^3$ (30-day average) can be met because of the possibility of monthly, seasonal, and even annual variations in ambient levels caused by variations in meteorology and production. The existing sources that can qualify for this option are four beryllium extraction plants and possibly a small number of machine shops. These sources were designed or modified to facilitate compliance with the 0.01 $\mu g/m^3$ ambient limit. In addition, these sources are located sufficiently far apart so that the ambient levels of beryllium in the vicinity of a source can be attributed to the emissions from that source.

2. Information received after proposal indicated that the open burning of beryllium-containing wastes could cause ambient concentrations of beryllium in excess of 0.01 $\mu g/m^3$. The scope of the promulgated beryllium standard was revised to prohibit the open burning of beryllium-containing waste because the control of emissions from such sources is not feasible. The standard does allow, however, disposal of beryllium-containing waste in incinerators that are regulated by the 10 grams per 24-hour limit. The disposal of beryllium-containing explosive wastes is covered in the standard applicable to rocket testing.

3. Comments were received which claimed that numerous machining operations use alloys containing low concentrations of beryllium and do not exceed the 10 gram per 24-hour emission limitation. An investigation of these comments revealed that alloys which include beryllium generally either contain a large amount (greater than 60%) or a small amount (less than 5%), and that approximately 8000 machining operations use the low-content beryllium alloys. A survey was conducted by EPA to determine if significant beryllium emissions could result from the operations which use low beryllium content alloys (e.g. stamping, tube drawing, milling, and sawing). (See Table 3.) The survey consisted of measuring maximum concentrations of beryllium in close proximity to the operations which generate beryllium emissions. The values measured, usually within one to two feet of the emitting operation, were very low.

The data presented in Table 3 are in terms of concentrations instead of an emission rate since the flow volumes close to the machining operations are very low and difficult to measure. The operations that were measured generally were not hooded and vented to the atmosphere but were operated openly in the shop building. In order to evaluate the potential emissions that could result from these operations, a properly designed hooding system was assumed that would ventilate the machining device according to the American Conference of Governmental Industrial Hygienists (ACGIH) guidelines[22] and the beryllium emissions were calcuated. The following additional assumptions were made:

Table 3.

EPA Survey of Be Alloy Operations

Date	Process	Concentration In Work Area	Alloy (% Beryllium)
July 1972	Machine shop - milling machine	65.8 $\mu g/m^3$ - 18" above tools	2
Aug. 1972	Machine shop - stamping & heat treatment	0.0891 $\mu g/m^3$ - 3 ft above heat treatment	2
July 1972	Machine shop - sawing	0.12 $\mu g/m^3$ - 2 ft above machine	0.5 to 2
Aug. 1972	Machine shop - drilling	0.0725 $\mu g/m^3$ - 18" from drill	2
Aug. 1972	Machine shop - drilling	0.0293 $\mu g/m^3$ - 2 ft from drill	2
Aug. 1972	Machine shop - stamping	0.251 $\mu g/m^3$ - 6" from stamping die	2
Aug. 1972	Machine shop - cutting & slitting	0.594 $\mu g/m^3$ - 1 ft from slit tool 0.159 $\mu g/m^3$ - 1 ft from saw	2
Aug. 1972	Machine shop - stamping	0.006 $\mu g/m^3$ 4" from die tool	2
Aug. 1972	Metal working - tube forming	0.0573 $\mu g/m^3$ - 8" from tube die	2
Aug. 1972	Machine shop - stamping & heat treating	0.0826 $\mu g/m^3$ - 8" from heat treatment Undetectable from die operation	2

a. An open hood area of 5 square feet.

b. Two machines operated continuously on a 24-hour-per-day basis.

c. The beryllium concentration of the ventilation air was equal to the concentration measured in close proximity to the machining operation.

d. A required ventilation flow rate of 300 CFM per square foot of open hood area.[22]

e. No emission control devices.

The highest concentration measured in EPA's survey was 65.8 $\mu g/m^3$ obtained during an alloy milling operation. This concentration is over 400 times higher than the average of measurements obtained for 10 other machine operations. It is suspected that this concentration is not representative of the machining operations due to the capture of unrepresentative alloy chips on the filter during sampling which would not be vented to the outside air. The average concentration of the 10 operations (excluding the high value of 65.8 $\mu g/m^3$) is 0.15 $\mu g/m^3$. Using 0.15 $\mu g/m^3$ and the assumptions given above, an uncontrolled emission of .02 grams/24-hour period is calculated. The results indicated that even if the emissions were vented, without prior treatment to the outside air, which was not the case in the operations tested, the emissions would be signficantly below the 10-gram-per-24-hour emission limitation. Accordingly, the standard was revised to exempt the machining operations which use the low beryllium content alloys. Five percent beryllium was used as the dividing line since this would exempt all of the innocuous sources of beryllium from coverage while

insuring that those sources which are most likely to cause ambient concentrations in excess of 0.01 $\mu g/m^3$ would be covered.

Environmental Impact

It is estimated that the impact of the standard on reducing beryllium emissions will be small since most of the potentially large beryllium emission sources are already well controlled.

The disposal of waste material collected by the additional control devices that are required for a few existing sources and the devices installed on new sources are potential sources of beryllium environmental contamination; however, this is not considered to be a problem because it is economically desirable to recycle beryllium waste due to its high value. Most gas streams emitting significant quantities of beryllium are controlled with dry collectors which produce a waste material that is generally easy to handle and recycle. This waste material is recycled or sold back to primary producers for reprocessing. Absolute filters are used in some applications as final filters to collect small quantities of beryllium from very low concentration gas streams. The beryllium collected by this type of filter cannot be easily recycled; therefore, filters are usually packaged after removal and buried in segregated dumps or stored in unused mines. Procedures to deal with this type of beryllium waste are well developed and currently in use. No additional environmental impact caused by the standard is expected from the disposal of final filters.

The use of wet collectors is not anticipated to be a problem because these collectors are rarely used strictly as an air pollution

control device, but more often as an extraction process control device allowing recycle of waste liquids to the process.

Economic Impact

Although the standard is not based on economic considerations, the economic impact of the standard is discussed below. Since most of the sources of beryllium emissions are already controlled and in compliance with the standard, the economic impact will be very small.

The beryllium processing industry includes the primary producers (extraction plants) which extract beryllium from ores and manufacture metal, alloy, and oxide forms. Secondary processors, such as ceramic plants, machine shops, and foundries, further process beryllium oxide, beryllium metal, or beryllium-copper alloy products for applications in electrical switchgear, electronic microcircuits, welding equipment, defense purposes, and nuclear reactors.

The extreme toxicity of beryllium requires the practice of good industrial hygiene to protect employees' health. This practice frequently includes collection of beryllium pollutants from ventilation ducts to prevent re-entrainment into the plant. The limitation on ambient beryllium concentration which will result from the standard has already been applied to government facilities and government contractors associated with the Atomic Energy Commission. This resulted from recommendations issued in 1949 by the Beryllium Medical Advisory Committee to the AEC.

Of four basic classes of manufacturing sources that emit beryllium--extraction plants, ceramic plants, machine shops, and

foundries--it is probable that only foundries will have to add control equipment beyond existing levels to meet the standard. It is estimated that there are hundreds of foundries which process very small quantities of beryllium compounds in conjunction with the manufacture of beryllium-copper alloy products. Because beryllium-copper alloy conventionally contains no more than 4 percent beryllium, only those facilities that handle relatively large quantities of material are likely to exceed the emission limitation of the standard, even in the absence of emission controls.

Based on the above, it is estimated that there will be little economic impact on the beryllium industry. Only large foundries will need to finance installation of fabric filters, or perhaps scrubbers, to meet the standard. The control costs are estimated to be on the order of 0-2 percent of individual company sales.

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MERCURY

The following information augments that given in the preamble to the promulgated regulations.

Health Effects

Vapors of elemental mercury are rapidly[3,4] and almost completely[1,2,3] absorbed via inhalation. Inhaled mercury vapors rapidly leave the lungs and gradually concentrate in other tissues.[4,5,11]

After exposure to elemental mercury vapors, central nervous system (CNS) effects predominate, with tremor and nonspecific neurasthenic symptoms;[7] renal damage may occur also.[6,7]

The differences in toxicity among the various forms of mercury are explained to a great extent by differences in their metabolism.[7] To react chemically with proteins and other molecules in the living organism, elemental mercury must undergo oxidation to the mercurous (Hg_2^{++}) or mercuric (Hg^{++}) ion,[8] and oxidation of most of the vapor probably takes place soon after absorption from the lungs, inside the red blood cells;[6,8] a small amount of elemental mercury that persists in the blood, however, plays an important role in the distribution of mercury to the brain after exposure.[4,9,10] After exposure to the vapor, mercury is eliminated in the inorganic form, mainly as mercurous and mercuric salts, and those complexes in which mercuric ions can form reversible bonds to tissue ligands; animal (rat) data show the excretion to follow two (to three) consecutive exponential curves of increasing half-life, and clearly, the slowest component, involving some 70% of the dose after brief exposure

(0.5-5 hours) to radioactive vapor, and characterized by a half-time of 20 days,[5] would play a predominant role in determining the cumulative body burden in clinically exposed animals.[8] The accumulated body burden of mercury approaches a steady state in such animals after approximately 60 days of repeated exposures, and the best available evidence suggests that humans attain a steady state level after approximately between six and eighteen months of exposure. Further interpretation of half-lives is difficult, in view of the time-related redistribution within the body[7,8] i.e., an uneven distribution among and within organs, combined with a slow excretion from, for example, the CNS and the kidneys. The data collectively indicate a risk of accumulation in critical systems upon prolonged exposure,[7,8] giving rise, for example, to a potential for selective brain damage.[8]

There exist few epidemiological data which provide scientifically satisfactory information about detailed dose-response relationships in man, even for a single mercury compound; this fact, however, is not unique for mercury, and there are, moreover, some data available for mercury vapor inhalation that make it possible to assess risks to some extent. Experience with mercury vapor comes almost exclusively from animal experiments and industrial exposures. Prolonged exposure in an industrial environment to about 0.1 mg Hg/m^3 involves a definite risk of mercury intoxication.[7] It is not possible, however,

to state a no-effect concentration since recent studies in the U.S. chlor-alkali industry[12] as well as some industrial data from the U.S.S.R. indicate that exposures as low as 0.01-0.05 mg Hg/m^3* can produce certain subtle, reversible effects.[6] Animal data from the U.S.S.R. indicate that still lower concentrations may produce certain deleterious effects,[7] i.e., changes in conditioned reflexes have been reported even at concentrations in the air of 0.002-0.005 mg Hg/m^3 when rats were exposed for several months; this work, however, has not yet been reproduced in other laboratories.

Elemental mercury has been shown to be carcinogenic (only at deposition sites, after intraperitoneal injection into rats),[13] whereas inorganic mercury compounds have not been so implicated. The latter are subject to conversion to methylmercury compounds by microorganisms.[14-17] Methylmercury compounds are considered to be by far the most hazardous mercury compounds, particularly via the ingestion of fish in which they have been concentrated through the food chain.[7,18] Methylmercury is more readily transferred across the placental barrier than is mercuric chloride or phenyl mercuric acetate.[18]

*The current U.S. Threshold Limit Value is 0.05 mg Hg/m^3 [21] The World Health Organization[23] recently established a "provisional tolerable weekly intake" of 0.3 mg of total mercury per person, of which no more than 0.2 mg should be present as methylmercury, CH_3Hg^+ (expressed as mercury).

Without knowledge of the accumulation rate of mercury in different parts of the CNS, the effects of continuous long-term exposure, and of the nature of particularly sensitive groups, it is not possible to estimate the concentrations to which the given industrial concentrations would correspond in general community exposures. Considering only differences in exposure over a one-year period (365 vs. 225 days, and a lung ventilation rate of 20 m^3/day vs. 10 m^3/work day) would yield an approximately threefold reduction; this means that a concentration in industry of 50 µg Hg/m^3 (the present U.S. TLV)[21] would correspond to a concentration in the general population of about 15 µg/m^3. At a lung ventilation rate of 20 m^3/day and an absorption of 80%, this corresponds to a daily absorption of about 250 µg. Occupationally-derived threshold limit values and maximum allowable concentrations do not take into account the extremes of youth, age and disease encountered in the general population.

In order to determine the level of mercury in the ambient air that does not impair health, the airborne burden must be considered in conjunction with the contribution of mercury from water and food. An analysis of the Japanese epidemics by the Swedish Commission on Evaluating the Toxicity of Mercury in Fish[19] led that group to conclude that an adult sensitive to methylmercury would be poisoned by an intake of about 4 µg/kg body weight/day. Application of a safety factor of 10 yielded an acceptable exposure of about 0.4 µg/kg body weight/day, or 30 µg/day for a 70 kg man. It was felt by this expert group that application of this safety factor provided

satisfactory protection against poisoning of the fetus, genetic lesions, and poisoning of children.

In view of the present limited knowledge as to effects of inhaled mercury vapor in the general population, and to best assure the requisite "ample margin of safety to protect the public health,"[20] the Environmental Protection Agency is adopting the prudent approach of considering exposures to methylmercury (diet) and mercury vapor (air) to be equivalent and additive. Diets containing fish contaminated at or exceeding the present FDA limit of 0.5 µg/g would lead to intakes in excess of 30 µg/day; however, it has been estimated that from average diets, over a considerable period, mercury intakes of 10 µg/day[22] could be expected. Thus the average mercury intake from air would have to be limited to 20 µg/day if the average total intake is to be restricted to 30 µg/day. Assuming inhalation of 20 m^3 air/day, the air could contain an average daily concentration of no more than 1 µg Hg/m^3. The ambient air level of 1.0 µg/m^3 (daily average) is considered by EPA to be sufficient to protect public health with an ample margin of safety from the effects of atmospheric mercury. This level was used as a guideline in establishing the mercury emission standard.

Development of the Standard

The basic approach used to develop a standard for mercury was essentially the same as that used for beryllium. First, an ambient level sufficient to protect public health from the effects of mercury was identified and then allowable emissions were derived from the ambient level by using meteorological procedures. The mercury standard was,

therefore, developed with the intention of regulating those sources that have the potential to emit mercury in a manner that could cause the ambient concentration guideline to be exceeded.

EPA conducted a characterization study of mercury emission sources to determine which sources should be regulated. The study included contracts[24,25] to develop information on mercury emissions and communications with pollution control equipment vendors, industrial representatives, trade associations, and pollution control experts. Further, visits were made to representative plants which had been identified to be sources of mercury emissions. Several plants were tested for mercury emissions and the results of these tests are presented in Table 4.

An emission inventory developed by EPA as a result of this study is presented in Table 5. The sources of mercury emissions can be placed in two general categories, those with emissions containing high concentrations of mercury where a gas stream has been in intimate contact with mercury, and those with emissions where mercury is included only in trace quantities or is a contaminant and is emitted in low concentration gas streams. Mercury cell chlor-alkali plants, primary mercury extraction plants, and secondary mercury plants fit the first category, whereas power plants, nonferrous smelters, consumptive uses of paints, and waste disposal fit into the second category. From EPA's investigation into mercury sources requiring regulation, it was found that mercury emissions from the second category would not, even assuming restrictive dispersion conditions and uncontrolled emissions,

Table 4.

Emission Testing of Mercury Sources

A. Mercury Cell Chlor-Alkali Plants

Date Tested	Plant Capacity T Cl2/Day	Emission Rate g/24-hour period
July 1971	160	4560* complete plant[26]
Aug. 1971	180	2740 process streams[27]
Jan. 1972	400	5150 process streams[28]
Feb. 1972	300	3030* complete plant[29]

B. Mercury Extraction Plants

Date Tested	Plant Capacity T Ore/Day	Emission Rate g/24-hour period
July 1971	200	53,070[30]
Feb. 1972	35	4891[31]
Feb. 1972	90	7548[32]

*The cell room emissions were measured only at two of the chlor-alkali plants.

Table 5.

Emissions of Mercury to the Atmosphere - United States Inventory*

		Emissions (Short Tons) 1968
Mining		2.6
Processing		100.6
	**Primary Mercury	55.0
	Secondary Mercury	0.5
	Nonferrous: Copper	31.0
	Zinc	9.7
	Lead	4.4
Reprocessing		3.4
	Paint	0.8
	Electrical Apparatus	2.6
Consumptive Uses		532.1
	Paint	215.0
	Agricultural	18.8
	Pharmaceuticals	2.6
	**Electrolytic Chlorine (mercury cell)	185.4
	Instruments	2.6
	Dental Preparations	1.2
	General Laboratory Use	4.8
	Other	3.0
	Coal-Power Plants	57.5
	-Other	34.5
	Oil-Power Plants	3.4
Incineration and Other Disposal		139.2
	Incineration	10.8
	Sewage and Sludge	4.4
	Other	124.0
	TOTAL	777.9

*Does not include estimates of crustal mercury emissions.
**Sources covered by the mercury emission standard (NESHAPS).

exceed 1.0 μg mercury/m^3 on a daily basis; therefore, they were not covered by the proposed standard. Chlor-alkali plants, primary mercury extraction plants, and secondary mercury plants were thoroughly investigated since these plants were indicated to be capable of exceeding the ambient mercury guideline. Although the mercury concentration of gas streams from secondary mercury plants is high, the volumes generated in the processes used in this industry are low and result in emissions that will not cause the ambient guideline to be exceeded. As a result, this source category was excluded from the standard. The information obtained through EPA studies indicated that mercury cell chlor-alakli plants and mercury extraction plants could under certain circumstances cause guideline levels to be exceeded and, therefore, were the only source categories regulated by the proposed standard.

An emission rate of 2300 grams per 24-hour period was calculated to be the maximum emission allowable in order to protect the ambient guideline concentration of 1.0 μg/m^3. Restrictive assumptions were employed in order to be reasonably confident that the calculated maximum emission rate would not result in a daily ambient concentration in excess of 1.0 μg mercury/m^3 under realistically possible circumstances. The assumptions and equations used to make the dispersion estimates are given in the background information report[33] published at the time the standards were proposed. The diffusion model assumed essentially ground level emissions vented from a single stack. The standard proposed to regulate mercury emissions to protect public health was therefore

established at 2300 grams per 24-hour period and applied to the emissions from mercury cell chlor-alkali plants and primary mercury extraction plants.

The proposed mercury standard was reviewed by several governmental and expert advisory groups prior to being proposed in the Federal Register on December 7, 1971.

Evaluation of Comments

All of the comments received during the comment period were evaluated, and the proposed standard was revised to reflect this evaluation. The revised standard was reviewed by several advisory groups before final promulgation. The following is an evaluation of the major comments and the resulting actions by EPA:

1. Some comments argued that the sources covered by the proposed standard contribute only a small percentage of the total mercury emissions in the United States and that the standard should apply equally to all sources of mercury emissions. The proposed standard was intended to protect the public health from the inhalation effects of mercury. EPA recognizes that mercury and its compounds constitute a multimedia contamination problem, i.e., evidence exists that all man-made uses of mercury alter its natural distribution in the environment; that such uses may cause or hasten additional deposits into water over and above those occurring naturally, thereby building up environment concentrations; and that mercury levels accumulate in the aquatic

biota with the result that potentially dangerous residue levels may be reached in foods consumed by man and animals. Current data on the environmental transport of mercury, however, do not permit a clear assessment of the effect of mercury emissions into the atmosphere on the mercury content in the aquatic and terrestrial environments. Results of ongoing research will determine if there is a need for more comprehensive control of mercury emissions into the air. The promulgated standard is intended to protect the public health from the effects of inhaled mercury.

Only two source categories (mercury cell chlor-alkali plants and primary mercury plants) have been determined, as noted above, to be capable of emitting mercury in a manner that may exceed the inhalation health effects limit of 1.0 $\mu g/m^3$. The selection of the two categories covered by the mercury standard was based on emissions inventories and meteorological conditions of all currently known sources of atmospheric mercury emissions. Other sources which emit mercury to the atmosphere do not cause 1.0 $\mu g/m^3$ level to be exceeded. A large coal fired power plant having a capacity of 1000 megawatts, a 500 foot stack, and a mercury content in the coal of 0.4 ppm[35] is calculated to emit 3700 grams of mercury per day. In order for such a plant to cause the 1.0 $\mu g/m^3$ ambient level to be exceeded, it would have to emit 360,000 grams of mercury per day assuming

poor dispersion conditions. The above example is an extreme case and does not typify an average situation. The mercury content of domestic coal ranges up to 0.5 ppm[37] and averages 0.2 ppm.[36]

2. The mercury ore processing industry commented that enforcement of the proposed standard would result in the complete closing of their industry. This is an economic issue and is discussed in the section of this report which discusses the economic impact of the mercury standard.

The mercury ore processing plants have the capability of causing daily ambient mercury concentrations in excess of 1.0 $\mu g/m^3$. Section 112 of the Act states that "The Administrator shall establish any such standard at the level which in his judgment provides an ample margin of safety to protect the public health from such hazardous air pollutants." No mention is made in Section 112 concerning the consideration of economics in developing a standard. This has been interpreted to mean that economics is not a major consideration when the public health is at risk. Consequently, the standard regulating mercury emissions from mercury ore processing plants has been promulgated.

3. Some comments argued that compliance with the existing Occupational Safety and Health Administration (OSHA) regulation or the Threshold Limit Value (TLV) guideline for mercury should be used to enforce the standard for the cell room, with a reasonable portion of a total plant's mercury emissions being assigned as the cell room emissions. The proposed standard required the cell room

emissions to be measured by a source test method provided in Appendix B to the standard (Method 2). Source testing by EPA has shown that the application of this source test method is difficult and only limited data have been obtained using this method. Little information, therefore, is available concerning the accuracy and workability of the proposed sampling method.

Many chlor-alkali plant cell rooms present severe source testing problems due to their design and construction. A major problem is that the volumetric flow rate can not be accurately measured due to cell room configuration. In most installations, cell room air is discharged through roof ventilators; however, several cell rooms are vented through the bottom floor, and one chlor-alkali plant does not have an enclosed cell room. Because of the cell rooms' large volume (300 ft x 150 ft x 40 ft for example), the large number of ventilation openings, and variations in the ventilation methods, the ventilation flow cannot be accurately measured by the proposed sampling method. EPA does have a proven method to sample emissions from a stack. The cell rooms can be designed and modified so that the stack sampling method can be used, but the cost of modifying an existing cell room so that room air is vented through stacks suitable for testing by the stack sampling method would be very large and no mercury control would be achieved by this expenditure. Further, there are no current control methods which are capable of removing mercury from large volumes of air having low concentrations of mercury. The only way EPA has found to limit the mercury emissions from cell rooms is by implementing

certain design, maintenance, and housekeeping practices. A list of these practices is available from EPA upon request.

Revising the standard to require only that the cell room be in compliance with the Occupational Safety and Health Administration (OSHA) concentration guideline could seriously compromise the intent of the standard since the occupational exposure guideline applies to the working environment. Complying with the OSHA regulation can be accomplished by increasing the ventilation rate of the cell room; this ventilation air can be exhausted to the atmosphere without treatment to remove mercury and would not result in any decrease in mercury emissions.

Considering the above information, the standard was revised to allow owners and operators the option of either modifying the cell room so that a stack sampling method can be used or complying with approved maintenance and housekeeping practices that will minimize mercury emissions from the cell room.

Source test data and calculations indicate that when such maintenance and housekeeping practices are used, 1300 grams per day is a reasonable estimate of emissions from the cell room. Therefore, when this option is chosen, an emission of 1300 grams per day will be assigned to the cell room. This permits emissions of not more than 1000 grams per day from the hydrogen and end box ventilation streams combined. Compliance of a source with the standard will be

determined by the reference method in Appendix B of the standard or an approved equivalent or alternative method. Under the housekeeping and maintenance practices option, the determination of compliance of the cell room emission will be based on the use of EPA-approved practices.

The following list of housekeeping and maintenance practices will reduce the mercury vapor concentration in the ventilation effluent from cell rooms. This list is subject to revision as more effective practices become available.

a. Chlorine cells and end-box covers should be installed, operated, and maintained in a manner to minimize leakage of mercury and mercury-contaminated materials.

b. Daily inspection should be made by operating personnel to detect leaks, and immediate steps to stop the leaks should be taken.

c. High housekeeping standards should be enforced, and any spills of mercury should be promptly cleaned up either mechanically or chemically or by other appropriate means. Each cell room facility should have available and should employ a well-defined procedure for handling these situations.

d. Floor seams should be smoothed over to minimize depressions and to facilitate washing down of the floors.

e. All floors should be maintained in good condition, free of cracking and spalling, and should be regularly inspected, cleaned, and to the extent practical, chemically decontaminated.

f. Gaskets on denuders and hydrogen piping should be maintained in good condition. Daily inspection should be made to detect hydrogen leaks and prompt corrective action taken. Covers on decomposers, end-boxes, and mercury pump tanks should be well maintained and kept closed at all times except when operation requires opening.

g. Precautions should be taken to avoid all mercury spills when changing graphite grids or balls in horizontal decomposers or graphite packing in vertical decomposers. Mercury-contaminated graphite should be stored in closed containers or under water or chemically treated solutions until it is processed for reuse or disposed.

h. Where submerged pumps are used for recycling mercury from the decomposer to the inlet of the chlorine cell, the mercury should be covered with an aqueous layer maintained at a temperature below its boiling point.

i. Each submerged pump should have a vapor outlet with a connection to the end-box ventilation system. The connection should be under a slight negative pressure so that all vapors flow into the end-box ventilation system.

j. Unless vapor tight covers are provided, end-boxes of both inlet and outlet ends of chlorine cells should be maintained under an aqueous layer maintained at a temperature below its boiling point.

k. End-boxes of cells should either be maintained under a

negative pressure by a ventilation system or should be equipped with fixed covers which are leak tight. The ventilation system or end-box covers should be maintained in good condition.

l. Any drips from hydrogen seal pots and compressor seals should be collected and confined for processing to remove mercury, and these drips should not be allowed to run on the floor or in open trenches.

m. Solids and liquids collected from back-flushing the filter used for alkali metal hydroxide should be collected in an enclosed system.

n. Impure amalgam removed from cells and mercury recovered from process systems should be stored in an enclosed system.

o. Brine should not be purged to the cell room floor. Headers or trenches should be provided when it is necessary to purge brine from the process. Purged brine should be returned to the system or sent to a treating system to remove its mercury content.

p. A portable tank should be used to collect any mercury spills during maintenance procedures.

q. Good maintenance practice should be followed when cleaning chlorine cells. All cells when cleaned should have any mercury surface covered continuously with an aqueous medium. When the cells are disassembled for overhaul maintenance, the bed plate should be either decontaminated

chemically or thoroughly flushed with water.

r. Brine, alkali metal hydroxide, and water-wash process lines and pumps should be maintained in good condition, and leaks should be minimized. Leaks should be corrected promptly, and in the interim, the leaks should be collected in suitable containers rather than allowed to spill on floor areas.

The apportionment of the mercury emission from the cell room was derived based on the following data and assumptions:

a. EPA has source tested two cell rooms and the emissions and plant data are presented below:

Date of Test	Rate (Tons Cl_2/day)	Ventilation Rate (CFM)	Emissions g/24 hours
Feb. 1972	300	290,000	1520[29]
July 1971	190	330,000	980[26]

b. The capacity of a large mercury cell chlor-alkali plant is of the order 500 Tons Cl_2/day.

c. The average cell room ventilation volume assumed for a 500 T Cl_2/day plant is 630,000 CFM (based on data given above).

d. The concentration of the ventilation gas stream is assumed to be 50 $\mu g/m^3$, the OSHA regulation (time weighed 8 hr average).

Based on the above data and assumptions, a mercury emission rate of 1285 grams/day was calculated. The emission rate apportioned to all cell rooms was rounded off to 1300 grams/day and will be assigned

to a cell room of any size if the housekeeping and maintenance practices are followed.

4. Some comments argued that variations in the meteorlogical conditions of specific locations and the production capacity of individual plants should be considered in the standard. This comment was considered and rejected because such a standard could be extremely difficult to administer under the time requirements of the Act and it would not be considered a "national emission standard". The procedure used to develop the proposed emission limit of 2300 grams per day is discussed in this report under "Development of the Standard". It is estimated that at least 1 to 2 years of study at each source would be necessary to obtain the required meteorological data to develop a standard for each source based on the specific meteorological conditions of that source. This approach is costly and would require a lag time which is inconsistent with the requirements of the Act; additionally, Section 112 of the Act directs the Administrator to prescribe national emission standards.

A proposed alternative that is consistent with being a national standard and which would avoid the problem of choosing a set of

meteorological conditions would be to prescribe the standard in the form of an allowable ambient air concentration and measure compliance by ambient air sampling. This concept is allowed in the beryllium standard for sources that have three years of measured air quality data which demonstrates that the beryllium ambient guideline will be met in the future. Similar ambient data is not available for mercury sources. In fact, a sampling method to accurately measure mercury levels of 1.0 $\mu g/m^3$ is not presently available; therefore, this alternative could not be used.

The question of allowing a proportional increase in the emission limit for plants of large capacity is essentially a question of economics versus health considerations. The larger plants will find it more difficult to meet the 2300 grams per day limit, but an increase in the emission limit could result in the ambient mercury concentration exceeding 1.0 $\mu g/m^3$.

After considering the above comments and alternatives, the mercury standard was not revised. The promulgated standard provides the maximum assurance that no source will emit mercury in sufficient quantity to cause the ambient concentration to exceed 1.0 $\mu g/m^3$ and, in addition, is a national emission standard whereas most of the other alternatives are not.

5. Some comments argued that the standard should not be set without considering demonstrated control technology for mercury. Section 112 of the Act does not indicate that technology for emission control be considered before a standard is promulgated The major consideration in developing a hazardous pollutant standard is protection of the public health.

Technology to control emissions of mercury is available but has not been applied to the primary mercury industry in the United States. A foreign mercury extraction plant which is well controlled and is approximately three times larger in capacity than the largest plant in the United States, has reported emissions of 450 grams per day[38] from this plant.

Information obtained from equipment vendors, industrial sources, plant operators, and public hearings indicate that the standard can be achieved in the mercury cell chlor-alkali plants with existing control technology. The larger plants will require more efficient control equipment to comply with the standard since their emissions are generally greater; however, available information indicates that the standard is achievable even for the largest plant. Emissions from the hydrogen and end-box ventilation system of the largest plant can be controlled to less than 1000 grams per day with existing technology. Other than good housekeeping and maintenance practices, there are no control techniques yet available to remove mercury from the cell room air. The cell room air can be limited to an estimated emission of 1300 grams per 24-hour period by use of good housekeeping and maintenance practices.

Environmental Impact

A mercury emission inventory for the United States in 1971 is given in Table 6. To determine the impact of the standard on reducing the mercury emissions from the affected source categories, a comparison of emissions before and after the implementation of the standard can be made. Assuming that the affected facilities are emitting 2300 grams of mercury per 24-hour period, the emissions from the primary mercury extraction plants will be reduced from 33.5 tons of mercury in 1971 to 5.5 tons annually, and electrolytic chlorine plant emissions will be reduced from 150 tons of mercury in 1971 to 26.9 tons annually. Thus, the mercury standard will have a substantial impact on reducing emissions from the regulated sources. The emission reduction that will be achieved in the affected sources after the standard is implemented represents about 22% of the total 1971 U.S. emissions.

The control of mercury emissions required to comply with the standard for both existing and new sources can generate control system wastes that can potentially cause considerable environmental impacts if not properly treated. However, methods are available to treat or dispose of these wastes; therefore, the atmospheric mercury emission standard will have only a minor adverse impact in other areas of environmental concern.

The simplest control for mercury emissions to the atmosphere is cooling to condense the mercury. Cooling can be indirect or direct. In indirect cooling, the mercury condenses and is retained

Table 6.

Emissions of Mercury in the United States by Source Category*

Category	Group	Emissions in Short Tons 1971	Emissions in Short Tons After Implementation of Standard (Annual)
Mining	Mercury and Non-Ferrous	2.5	
Processing	**Primary Mercury	33.5	5.5
	Secondary Mercury	0.5	
	Non-Ferrous: Copper	35.0	
	Zinc	11.0	
	Lead	5.0	
Reprocessing	Paint	0.8	
	Electrical	2.6	
Consumptive	Paint	229.0	
	Agricultural	8.1	
	Pharmaceuticals	4.2	
	**Electrolytic Chlorine (mercury cell)	150.0	26.9
	Instruments	2.6	
	Dental Preparations	0.9	
	Other	6.9	
	Coal - Power Plants	59.3	
	Other	31.8	
	Oil	10.2	
Incineration and Other Disposal	Municipal	10.8	
	Sewage Sludge	4.4	
	Other	77.5	
		686.6	

*Does not include estimates of crustal mercury emissions.
**Covered by the mercury emission standard (NESHAPS).

for recycle or sale. In direct cooling, e.g. water scrubbing, the water is usually recirculated after using centrifugal or gravitational separation to remove the mercury. However, some additional treatment is eventually required to clean the water. In most cases, the water used for air pollution control can be treated in facilities currently utilized to prevent mercury discharges into the water.

A widely used advanced control technique for particulate mercury removal is the mist eliminator. Residues in these devices are removed by gravity and washing with a recycle liquid. Another advanced control method is chemical scrubbing. In such a system, components of the scrubbing liquor react chemically with mercury to form mercury compounds that are subsequently recovered from the solution by various methods. The scrubbing solution is recycled but a bleed stream from the scrubber system is generally necessitated and requires additional treatment to remove mercury. Mercury removal methods from liquid streams are available and can be used to treat bleed streams.

The use of adsorption beds is a highly efficient advanced control method for removing mercury from gas streams. Two primary types are available: (1) chemically treated activated carbon beds and (2) molecular sieves. The use of activated carbon produces a solid waste that requires ultimate disposal since no acceptable method of completely regenerating the spent carbon is currently available; however, little environmental contamination results because this waste is properly disposed of by the sources in segregated dumps. Ideally, most of the mercury collected can be reclaimed by retorting the spent carbon, but this usually destroys

the carbon structure and necessitates disposal of the decomposed carbon that contains small amounts of residual mercury. This waste can be disposed of with little environmental impact in appropriate dumping sites. The use of regenerative molecular sieves does not involve as great a solid waste disposal problem because of the sieve's much longer bed life and because retorting to remove the mercury prior to disposal of the bed is not required.

In general, control methods required to control mercury emissions to levels within the emission standard will produce waste products that may require disposal; however, appropriate disposal methods are available and the adverse environmental impact caused by the standard will be minor.

Economic Impact

Although the standard was not based on economic considerations, EPA is aware of its economic impact[34] and considers it to be reasonable under the circumstances. Because mercury is an international commodity, world prices determine the fortunes of the U.S. domestic mercury mining industry. Historically, mercury prices fluctuate greatly in response to small changes in demand or supply. The metal is on the strategic and critical materials list and is subject to stockpiling by the General Services Administration.

Domestic mercury mines are considered high-cost producers in relation to foreign producers. For comparative purposes, U.S. ore averages about 5 pounds of mercury per ton, whereas Spanish and Italian ores average, respectively, about 50 and 15

pounds of mercury per ton. Marginal prices required for domestic production range from $360 to $400 per flask for underground operations and from $270 to $300 for open-pit operations.

Due to a decline in demand for mercury and a subsequent world overproduction, the price of mercury decreased from $404 per 76-pound flask in 1969 to a low of $145/flask in April 1972. As a result, the number of U.S. primary mercury ore processing plants in operation declined from 109 in 1969 to fewer than 10 in April 1972. The price of mercury has increased to $320/flask in March 1973 due in part to more effective European marketing practices and an international devaluation of the U.S. dollar. This increase, however, has not been sufficient to cause the domestic industry to reopen the mines that were closed. Currently only 6 or 7 primary mercury extraction plants remain in operation.

The effects of international trade and stockpiling upon the domestic mercury mining industry can be shown by the following 1968 statistics from the Bureau of Mines:

Source	Supplies (76# Flasks) 1968
U.S. Mines	28,874
Metal Imports, Net	16,374
Secondary Metal Recovery	13,670
GSA and AEC Releases	20,710
TOTAL	80,628

Based on these data, domestic mines contributed 36 percent of the U.S. supply available for consumption and industrial stocks at a time when the price was high (approximately $535). Preliminary

statistics released by the Bureau of Mines show U.S. mine production declining to 6,296 flasks in 1972. Net imports increased to 28,778 flasks, and the metal recovered from secondary mercury operations has remained fairly constant and was 12,598 flasks in 1972.

Demand for mercury is concentrated in the chlorine-caustic production industry, electrical products manufacturing (batteries, lamps, apparatus, wiring devices), and paints and allied products. Total industrial consumption in 1968 was 75,422 flasks; and in 1971, it was 52,475 flasks. It is used in the chlorine-caustic industry as a cathode in mercury-amalgam cells for the electrolysis of sodium chloride brines. The increased use of diaphragm cells in place of mercury cells, as well as the use of more efficient mercury cells, has been the recent trend in the chlorine-caustic industry. One significant factor is the emphasis on restricting mercury discharges into water. As a result, consumptive use of mercury for this particular application may be trending downward. A drop in consumption of mercury for cells from 17,000 flasks in 1968 to 15,000 flasks in 1970 to 12,260 in 1971 suggests this.

A domestic mercury mine processing 100 tons of ore per day will require an investment of approximately $108,000 in control devices to meet the standard. This amounts to 27 to 36 percent of the capital invested in processing equipment. The annualized cost of $32,000 will amount to about 4.5 percent of sales, based on a current sales price of $320 per flask.

The value of additional recoverable mercury will partially offset the control costs. Based on the current depressed market, the net control costs will have to be absorbed by the producers, possibly forcing shutdown of some roasters. Those affected will be the marginal direct-fired ore roasters that have no controls. No impact is seen for the retort operations because these are probably already meeting the standard.

Some 16 companies operate 29 domestic mercury cell chlor-alkali plants. The total chlor-alkali industry is comprised of 66 plants, which includes 37 diaphragm-cell plants. The mercury cell chlorine process accounts for about 25 percent of the U.S. production of chlorine and caustic.

The capital investment required to control a 100-ton-per-day mercury cell chlorine plant within the standard is about $160,000 for the process gas streams. This assumes that cell room good housekeeping practices are in effect. The original plant investment for such a plant is approximately $10 million; therefore, the required control cost for this size plant is about 1.6 percent of the original investment. The annualized cost for controls in this case is approximately $48,000. The annual sales for this operation will yield an estimated $5.3 million in chlorine and caustic products, and the annualized cost will amount to 1 percent of sales.

The future of the chlorine-caustic industry appears healthy. Demand for chlorine is expected to grow at an annual rate of 6 percent projected from 1971. Demand for caustic soda will grow at least at the same rate as the demand for chlorine, and perhaps faster.

Prices for chlorine and sodium hydroxide have been rising steadily through the sixties into 1971. Based on these trends, the cost of control will be passed forward to the consumer. Use of these two basic commodities is so diverse that any price increases will be well dispersed through all manufacturing activities. High-grade caustic, which can be produced by mercury cell plants at lower cost than by diaphragm cell plants, will be needed in those market areas serving the textile and plastics industries. This should keep those competitive mercury cell plants operating in spite of increased air and water pollution abatement costs.

The older, marginal mercury cell plants may be closed, probably to be replaced by diaphragm-cell plants. If this occurs, the decline in mercury usage for the chlorine-caustic industry will accentuate the depressed conditions in the domestic primary mercury production industry.

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